

Territorial Changes and Effects on the Health of the Populations Surrounding

Case Study: Itaqui Port, Northeast of Brazil

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Received: June 8, 2016 Accepted: August 9, 2016 Online Published: September 27, 2016

doi:10.5539/jsd.v9n5p43

URL: <http://dx.doi.org/10.5539/jsd.v9n5p43>

Abstract

This study addresses the territorial changes and health conditions of populations living in the area affected by the Porto do Itaqui Thermal Power Plant (TPP), specifically the Vila Maranhão, Cajueiro, Camboa dos Frades, Nova Camboa dos Frades and São Benedito communities located in the municipality of São Luís – MA, Brazil. The data consisted of 191 interviews that were conducted from January to October 2013. The results showed that the individuals from these communities had a low educational level, with most having attended school only up to the elementary level, which contributes to a high rate of unemployment or of individuals surviving on temporary jobs. The communities' environmental awareness indicated that the main difficulties were associated with the lack of public policies, particularly regarding roads, garbage collection, low sanitation coverage, increased violence, unemployment, and informal employment. Regarding air quality, the results showed that the air pollutant concentrations still met the established limits, although the Camboa dos Frades community showed greater health problems due to a direct influence of pollutants. The reconfiguration of land use and land cover caused changes in the organization of the communities and the environment, reflected by the predominance of semi-urbanized areas and changes in the flows of small bodies of water caused by siltation from erosion. The identification of health conditions and the changes occurring in the communities affected by projects such as the TPP is important; therefore, public policies for urban mobility, spatial planning, health, education and urban safety should be proposed for such communities.

Keywords: environment, health, rural community, thermal power plant

1. Introduction

An understanding of the socio-environmental dynamics and types of land uses that reconcile economic growth with the quality of life of coastal populations is essential for achieving social, economic and environmental sustainability.

The appropriation of space for industrial activities in the coastal zone powerfully affects the socioeconomic reality and social relationships with the natural environment. The development of economic activities without previous environmental planning leads to a reorganization of the territory that demands the establishment of sustainable strategies and actions that consider the inhabitants of the affected region.

The territory adjacent to the Industrial District of São Luís (*Distrito Industrial de São Luís* – DISAL) comprises the Vila Maranhão, Cajueiro, Camboa dos Frades, Nova Camboa dos Frades and São Benedito communities. This area is vulnerable to public and private interventions because of its natural potential and the advantages of its strategic location that favor the development of multiple economic activities.

One of the events that contributed to the reconfiguration of this area was the installation of the Porto do Itaqui Thermal Power Plant (TPP), which was built to generate electricity through coal combustion with low sulfur content and with a nominal electricity generating capacity of 360 MW.

Similar to several other types of power generation, thermoelectric power plants also have environmental impacts, such as contributing to global warming through the greenhouse effect and acid rain. The toxic metal contamination of soil has been primarily recognized as a problem associated with metal industries and thermal power plants (Flues et al., 2008). Natural gas combustion releases large amounts of oxidants and reducers into the atmosphere that may cause respiratory diseases in humans, in addition to being a non-renewable fossil fuel (Vilella & Silveira, 2007).

Studies have indicated that fine particulate matter less than $2.5\ \mu\text{m}$ in diameter ($\text{PM}_{2.5}$) have serious adverse effects on human health, affecting the lungs and alveolar regions, while ultrafine particles ($< 0.1\ \mu\text{m}$) may be transported into the systemic circulation (Song et al., 2016).

The Porto do Itaqui Thermal Power Plant operation resulted in changes in the socio-cultural organization and health of the community inhabitants living in its area, causing respiratory diseases and several other harmful effects on health.

Accordingly, this study aimed to evaluate the territorial changes that affected the daily life and health of the populations living near the Porto do Itaqui Thermal Power Plant. Additionally, the consequences of this project on biodiversity, natural resource access, air quality and environmental risks, among other factors that substantially affect these populations' quality of life, were also investigated.

2. Methods

This study was conducted in the rural communities of Vila Maranhão, Camboa dos Frades, Nova Camboa dos Frades, São Benedito and Cajueiro, which are located in the municipality of São Luís (MA) (Figure 1). They are located in the area under direct influence of the Porto do Itaqui Thermal Power Plant that was installed in the Industrial District of São Luís, State of Maranhão, Brazil.

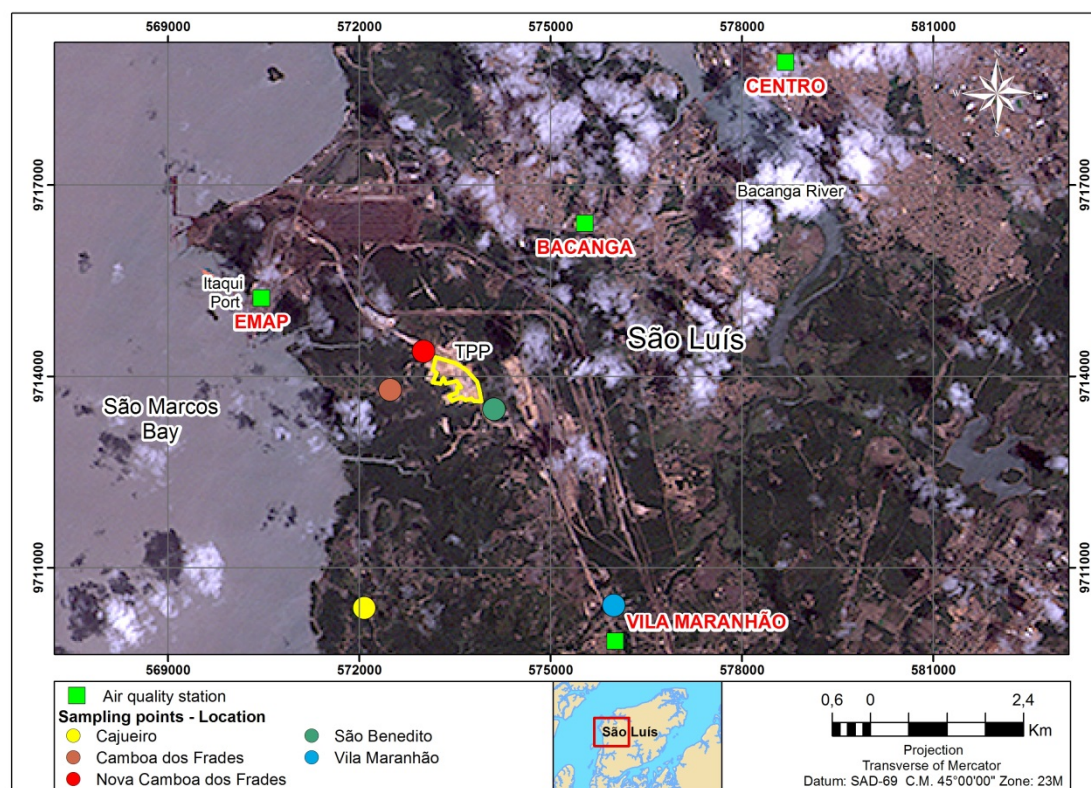


Figure 1. Location of the study area

Initially, a literature review was performed to identify the most pertinent information about changes resulting from the thermal power plant implementation. This literature review focused on the risks to the environment and the health of the surrounding population, guiding and justifying the entire study.

This is a descriptive study with a critical approach toward the socioeconomic, sanitary, environmental and health issues of the area affected by the Porto do Itaqui Thermal Power Plant that considers both quantitative and qualitative aspects.

The census tracts adopted by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* - IBGE) in the region were grouped into clusters (sampling strata), considering spatiality and homogeneity regarding lifestyle, occupation, income and the use of environmental resources.

The study consisted of 191 interviews conducted from January to October 2013 using semi-structured questionnaires that aimed to report the socioeconomic aspects, describe the environmental perceptions and identify the health conditions of the communities. Microsoft Office Excel 2007 software (Microsoft Corp., Redmond, WA, USA) was used for data entry, data processing and graph and table preparation.

A proportional sampling method for discrete data was used to determine the sample size (Rodrigues, 2006), according to the equation 1:

$$n_0 = \frac{z^2 pq}{e^2} \quad n = \frac{n_0}{1 + \frac{n_0}{N}} \quad (1)$$

where:

n_0 = Number of the initial sample

z_α = Z-score

α = 0.05

e = Maximum Tolerable Error

p = Proportion of the Main Event

q = Complementary Proportion

N = Population Size

The number of interviews conducted for each cluster and the investigated communities are shown in Table 1.

Table 1. Number of Interviews by Cluster

Strata	Interviews	Locations
Cluster 1	95	Vila Maranhão
Cluster 2	96	Cajueiro, Camboa dos Frades and São Benedito

In addition to the interviews conducted in the communities and the monitoring of the field research, some adjacent public places (schools, healthcare centers, police stations, community and religious centers) and other public environments were visited. The perception of the community about territorial changes and the social, economic and environmental impacts were analyzed from a qualitative approach. Information regarding health indicators was obtained from the basic guide of the Department of Environmental Health Surveillance and Occupational Health (*Departamento de Vigilância em Saúde Ambiental e Saúde do Trabalhador*) (Brasil, 2011).

The analysis of air quality in the area affected by the Porto do Itaqui Thermal Power Plant was based on secondary data from the monitoring stations located at the Maranhense Port Administration Company (*Empresa Maranhense de Administração Portuária* – EMAP), Itaqui Port, São Luís Center, Vila Maranhão, Bacanga and State University Maranhão (*Universidade Estadual do Maranhão* – UEMA). These stations provide continuous air quality data (24 hours a day, 7 days a week). The results are integrated, and the hourly averages are stored in local data loggers.

The data were compared to the National Environment Council (Conselho Nacional do Meio Ambiente – CONAMA), Resolution N°. 003/90 that establishes air quality standards, sampling methods and air pollutants analysis, using the primary limit as the reference standard.

High-resolution images for the years 2003 and 2012 were used, allowing an understanding of the evolution of the land cover, the visualization of different classes of land-use coverage and the reconfiguration of the existing landscape. The scale adopted for the vectorization of land cover units was 1:2,500.

The following resources were used in the vectorization of the images: Aerial image, spatial resolution of 1 m (*Aerolevantamentos e Consultoria Ltda.*, 2001 - AEROCONSULT); Pleiades 1B image, spatial resolution of 0.5

m for the year 2012; image processing software *SPRING 5.1.3*; and software to produce a thematic map, *ArcGis 9.3*, demonstration version.

The information was correlated to highlight the burden experienced by the investigated communities regarding essential basic services such as housing, sanitation, education, health and transportation.

3. Results and Discussion

3.1 Situational Diagnosis of the Socioeconomic Profile of the Communities

The interviews performed in this study focused on the heads of families or their spouses, who were between 26 and 50 years of age, with higher percentages in the communities of Vila Maranhão (48%), Camboa dos Frades and Nova Camboa dos Frades (57%), Cajueiro (42%) and São Benedito (40%).

A low educational level and illiteracy among several individuals were identified in the studied communities. The exception was Vila Maranhão, where individuals had higher educational levels, including undergraduate degrees.

According to Silva (2008), an impaired quality of life is associated with low educational levels because individuals with such levels of education have little knowledge of environmental and health issues, which significantly increases the problems associated with environmental health and public health.

Regarding the time that the respondents resided in the study areas, 39% of the respondents from Vila Maranhão had lived in that community for over 30 years; the majority (46%) of the respondents from Nova Camboa and Camboa do Frades had resided in these communities for 2 to 4 years. These data demonstrated that the region became more “attractive” after the thermal power plant installation because the new residents believed that they had a higher chance of being compensated by vacating the area when they were living in an area where some families had been already compensated. In São Benedito, 36% of the respondents had lived in the community for 20 to 30 years, and in Cajueiro, 71% had resided there for 10 to 20 years, demonstrating that most of these communities had developed when no industrial speculation had affected these places, particularly in the case of the thermal power plant installation.

Regarding jobs, a significant number of unemployed individuals were identified, with Nova Camboa dos Frades and Camboa dos Frades each presenting an unemployment rate of 47%, São Benedito, 67%, and Cajueiro, 46%. These individuals regard themselves as unemployed; however, they reported working temporary jobs to survive and receiving benefits from the family allowance program. In Vila Maranhão, most of the population (83%) works in different fields, particularly teachers, housekeepers, sales personnel, self-employment, drivers, fishermen and laundresses.

3.2 Current Overview of Perceptions of the Environment by the Communities

Environmental attitudes comprise a set of perceptions that in turn are directly associated with the culture and experience of each individual (Tuan, 1980).

The populations analyzed in the current study demonstrate concerns about the environmental conditions and the absence of actions associated with environmental protection. When asked about the environmental impacts, their main responses were associated with vegetation degradation in Nova Camboa and Camboa dos Frades (63%), Vila Maranhão (43%), Cajueiro (70%) and São Benedito (50%). However, other factors were also cited as “impactful”, such as variable and higher temperatures, water pollution and the recurrence of diseases (Figure 2).

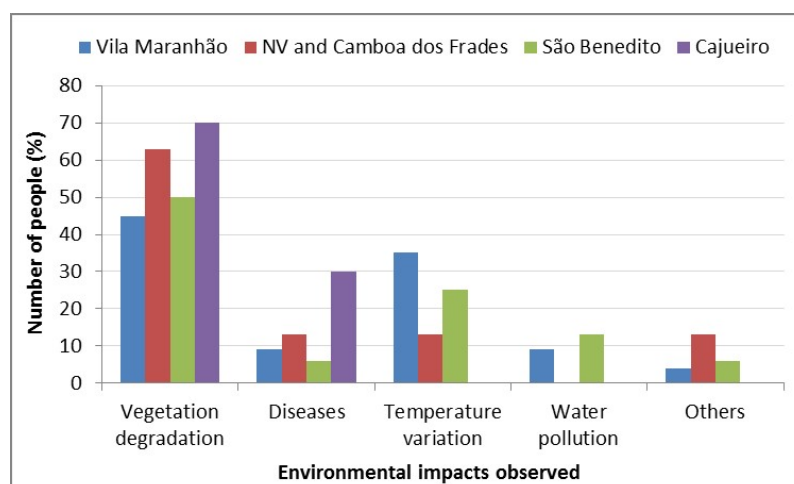


Figure 2. Environmental impacts observed by the population interviewed in the studied area

Regarding public policies, safety is a major concern for the community of Vila Maranhão, where 51% of respondents consider the safety situation alarming. They reported increasing robberies and thefts, an increasing spread of drugs among young people and the absence of police in that locality.

Another aspect reported by the respondents is the lack of infrastructure, mainly regarding paved streets, garbage collection, poor public transportation and low sanitation coverage.

A low use of local labor due to the lack of professional qualifications was also observed. This caused a migration to the informal economy and a weakening of the communities its economic and social base.

The environmental and health status of the populations from Nova Camboa dos Frades and Camboa dos Frades are at risk because this area is directly affected by the thermal power plant. Reports from residents indicate that the furniture is always covered with dust and its inhalation causes constant fatigue and respiratory problems, particularly among children and the elderly.

The vegetation surrounding the thermal power plant is also affected by soot. The upper layers of plants manifest a gray coloring and several changes in their developmental process. Respondents said that fruits, such as cashew, display a fragile appearance with stunted growth and reduced abundance, in addition to harboring cracks that hamper their consumption.

3.3 Integrated Analysis of the Impacts of the Coal-Fired Thermal Power Plant and Its Effects on Health

In the process of power generation, the coal-fired thermal plant produces a large amount of waste, liquid effluents and air emissions that should be analyzed to identify the level of severity and their effects on human health. These wastes, liquid effluents and air emissions may vary depending on a number of factors, such as the type of technology used, combustion, coal chemical composition and equipment, among others. Notably, the greatest environmental impacts of this process occur in the coal mines and mainly affect water resources, soil and the land relief of the surrounding areas (Aneel, 2002).

In the coal-fired thermal plant, among the most significant air pollutants are always those of the pollutant group directly associated with the use of this fuel, namely particulate matter (PM), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), photochemical oxidants and minor elements.

Fine particulate matter exposures have been consistently associated with severe health effects, resulting in increased hospital admissions and mortality that are mainly associated with respiratory and cardiovascular diseases (Pascal et al., 2014).

Air pollution is a severe public health problem associated with industrialization and urbanization. The World Health Organization has associated more than three million premature deaths worldwide during 2010 with pollution by particulate matter (Gao et al., 2015).

Total suspended particles cause serious health problems. The smaller the particle size is, the greater the effect on health, with significant resultant changes occurring in the health of individuals with lung diseases such as asthma and bronchitis.

Burnett et al. (2014) found strong evidence for a causal relationship between long and short exposure to PM_{2.5} (particulate matter 2.5 µm in diameter) and cardiovascular effects, respiratory problems and mortality.

The main environmental problems caused by emissions of this pollutant are associated with damage to vegetation, reduced visibility and soil contamination.

The data recorded during 2011 indicated a trend towards an increase in this pollutant's levels during the period from July to December, which coincides with the dry season and increased wind speed. However, concentrations above the limits established by CONAMA Resolution N°. 003/90 were not observed, considering the annual geometric mean that establishes a limit of 80 µg/m³ (Figure 3).

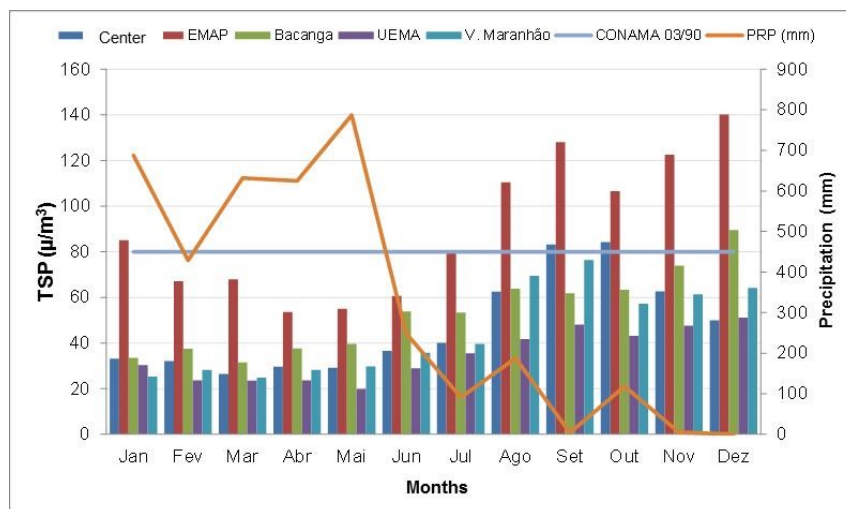


Figure 3. Mean concentration of Total Suspended Particles (TSP) and precipitation (PRP) during 2011

Sulfur dioxide is one of the main components of inhalable particles. Notably, individuals with asthma and chronic diseases, such as heart and lung disorders, are more sensitive to SO₂, which may even cause eye irritation. Regarding the environment, high SO₂ concentration may lead to the formation of acid rain, causing corrosion of materials and damage to vegetation (Atănăsoae, 2009).

The current study revealed that SO₂ results from the combustion of sulfur contained in coal, with potentially harmful effects on the mucous membranes that may cause muscle spasms and upper airway muscle contractions.

At high concentrations, SO₂ causes a burning sensation of the mucosa, coughing, difficulty breathing, and a sensation of suffocation. The presence of sulfur oxides in the environment is manifested by both direct damage to plants and changes in water and soil composition.

Negative effects of this gas on health were observed in the communities analyzed in the current study, particularly in Nova Camboa dos Frades and Camboa dos Frades, which are closer to the thermal power plant. Several reports indicate that air pollutants are already causing damage to the health of the community, affecting the respiratory tract (62%), skin (13%) and vision (25%).

The self-declared diseases that affect the population must be analyzed to understand the health status of the localities involved in this study. Records from the interviews indicate that the most common illness in the community is influenza, affecting 45% in Vila Maranhão, 24% in Nova Camboa dos Frades and Camboa dos Frades, 36% in São Benedito and 38% in Cajueiro. The significant incidence of respiratory diseases in these communities is noteworthy.

The assessment of the impacts to human health integrated with the environmental studies provides information about the consequences and effects on quality of life, health and well-being resulting from the pressures caused by the activities of thermal power plants on the environment. Moreover, such assessment extends the discussion to the inequality between the social groups who are subjected to the influence of the plants' operational activities.

3.4 Land Use and Land Cover

The area allocated to the Porto do Itaqui Thermal Power Plant was located in the G module of the Industrial District of São Luís in an area of 50,000 m² at an approximate 5-km distance from the Port Complex of Itaqui. For

this construction, the Vila Madureira community had to be relocated because it was situated exactly in the area that is now housing the physical facilities of the project, along the BR-135 highway in the Itaquí-Bacanga area. This community relocation caused social and environmental changes in the territory, particularly considering the populations directly affected.

The map prepared from 2003 satellite images (Figure 4A) shows the area of the TPP before its construction, where a more preserved green area may be observed. In contrast, the map based on 2012 images (Figure 4B) illustrates the project already installed and allows an analysis of the temporal evolution of land use in the region.

The map of land use and land cover, representing the landscape units of the areas surrounding the Porto do Itaquí Thermal Power Plant, shows the territorial changes, as presented in Figures 5 e 6, respectively referring to the 2003 and 2012 maps.

The analysis of the maps invites reflection about the use of areas with the potential for preservation and their intensive use for industrial sector activities. Carvalho (2009) considers that the impact of the projects installed in the Industrial District, even following the laws, are not appropriate for maintaining a local equilibrium because they cause a number of negative impacts to the environment.

Fthenakis and Kim (2009) indicated that the fuel production cycle from coal directly and indirectly affects the pattern of land use during the stages of mining, processing and electricity generation, which changes the existing landscape, destroys the soil and removes vegetation.

The vegetation in this region is composed of mangroves and fragments of upland forests that present different strata, characterized as “young secondary forests” and “old secondary forests” with a predominance of babassu palm trees that usually occupy anthropized areas.

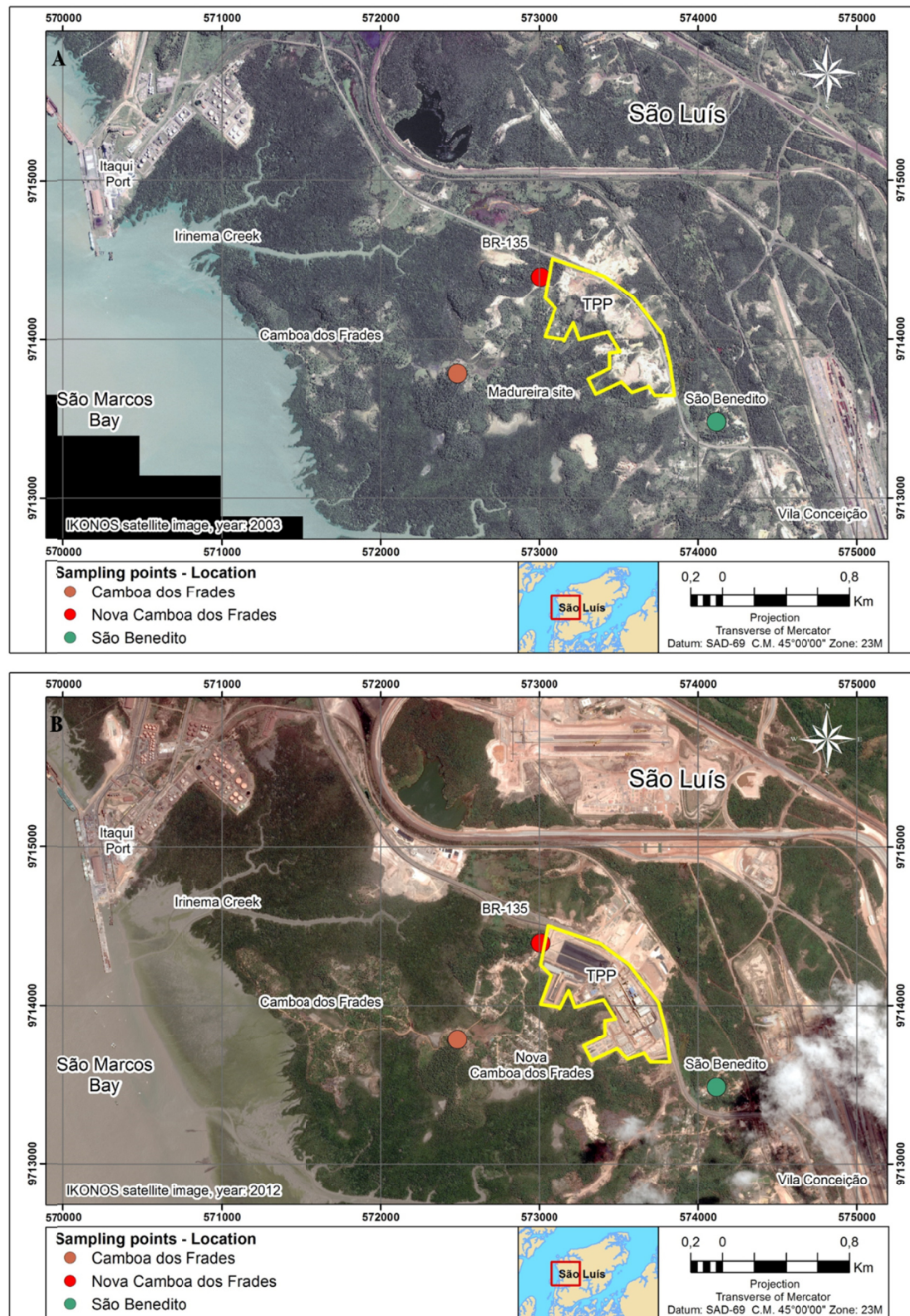


Figure 4. Map of the temporal evolution of the area affected by the implementation of the Porto do Itaipu Thermal Power Plant for the year 2003 (A) and 2012 (B)

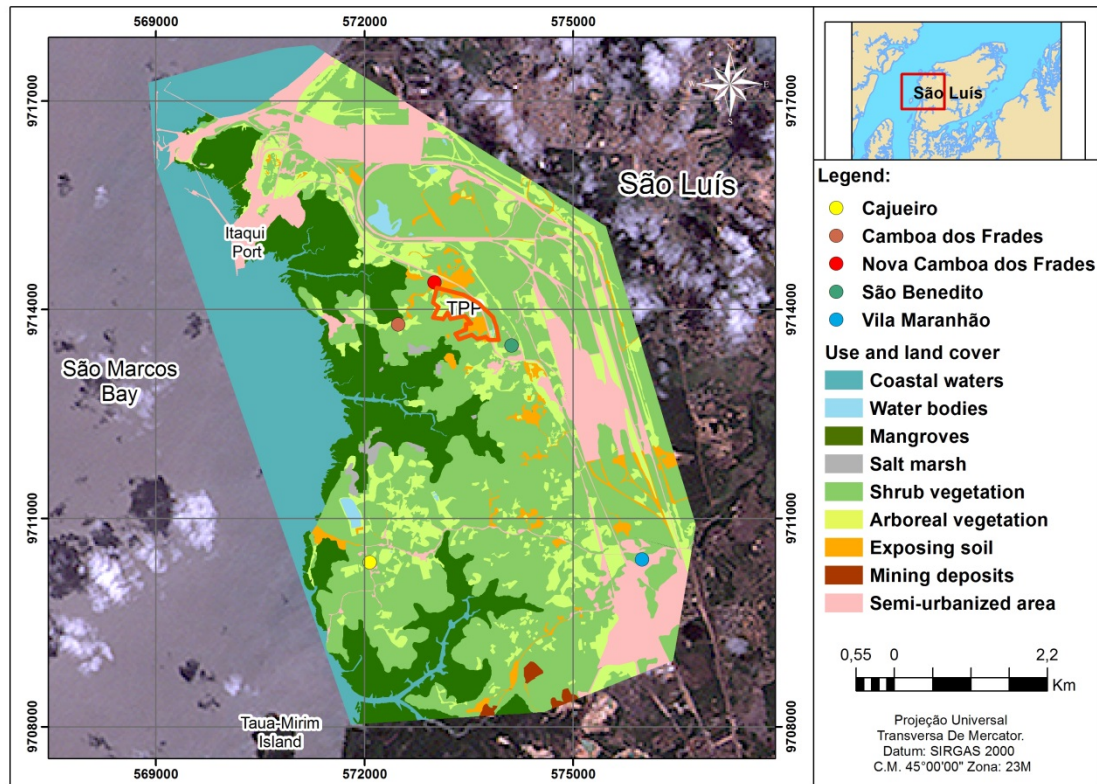


Figure 5. Maps of land use and land cover from 2003

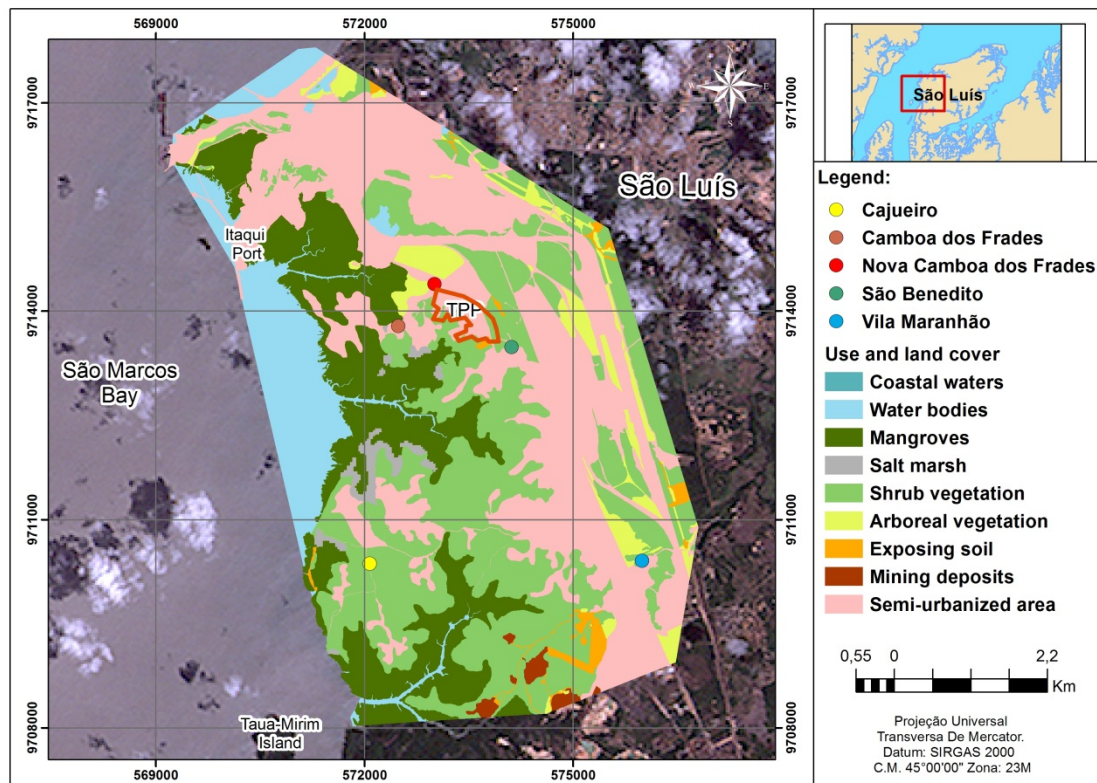


Figure 6. Maps of land use and land cover from 2012

In general, the devastation of vegetation occurs in two phases: during the installation of projects, with vegetation removal, and then during the operation phase, with the emission of pollutants and release of solid waste.

Of note, the flows of small bodies of water that drain the region were modified by silting from erosion, which is attributed to the devastation of riparian forests due to the installation of the project in that area.

A predominance of semi-urbanized areas was also present that, in general, characteristically reflect both rural and urban lifestyles. This preponderance is associated with industrial development and is based on the valorization of the area and real estate speculation. The installation of large industries is a factor responsible for the increase in the population in areas adjacent to the Industrial District of São Luís; however, it is still premature to state that the installation of this TPP contributed to this growth.

The Porto do Itaqui TPP was represented as a threat to the population residing near the area of interest, with socio-environmental consequences and compulsory withdrawal. As a form of resistance, the residents organized themselves and united with other social movements, seeking recognition of their rights to maintain their lifestyle and territories (Little, 2002), in addition to showing interest in environmental conservation.

Otoni (2005) states that sometimes the communities affected by major projects mobilize and manifest against a particular situation or some state action policy that favors large projects. However, the intense asymmetry of power between the social classes and their social actors hinders the negotiations, and in most cases, the biggest economic power group wins the dispute.

Vila Madureira was the community affected by the population relocation due to its proximity to the place chosen for the implementation of the TPP and by the fact that this community had a greater percentage of households directly affected by the project. The community of Camboa dos Frades was not contemplated in the discussions and negotiations, even though it was located in the vicinity of the project.

The entire negotiation process regarding the displacement of Vila Madureira was conducted by the Social Responsibility Sector of the TPP, which very “cleverly” approached the Residents Union board and, through its sociologists, social workers and psychologists, conducted continual visits to the village to conduct a systematic endeavor of persuasion. The promises made to residents consisted of compensation offers, which, in most cases, constituted approximately R\$ 1,200.00 and a titled and furnished house in a residential complex to be built for this purpose, in addition to transportation for the displacement. Without further resistance, the displacement to the residential “Vila Nova Canaã” that was built by the TPP in the municipality of Paço do Lumiar, approximately 40 km from the Vila Madureira village, occurred in April 2009 (Sant’Ana Júnior & Alves, 2010).

Carvalho (2011) states that in the initial period after the displacement, the population was dissatisfied with the new territory, particularly due to an attachment to the former territory and the identity traits associated with it. Saquet (2010) considers that in this context, identity occurs as a process and a relationship, signifying simultaneous spatiality and territoriality.

Sant’Ana Júnior and Alves (2010) analyzed the socio-environmental conflicts in Maranhão and observed the situation of groups that were displaced, noting that people reported regret for having accepted the compensation. Most of the time, these resources are insignificant if valued in terms of the environmental and social services for these groups, which call themselves “aggrieved”. Additionally, they reported the loss of their reference because after the displacement, they rarely stayed together with their relatives, which invariably results in loss of the cultural identity of the traditional community, its values and beliefs.

Even with the fulfillment of indemnity claims and compensation for the losses incurred during the period of expropriation and relocation of the owners and residents of the affected areas, the impacts associated with these actions remain germane, particularly those impacting the living and communal spaces of families and communities.

4. Conclusion

The results confirm that TPPs installed near traditional communities and coastal ecosystems have severe impacts on the quality of life of the surrounding population, artisanal fishing, health and the environment.

The environmental awareness of the communities analyzed in this study revealed that the main difficulties identified were associated with the lack of infrastructure, particularly regarding paved roads, garbage collection, public transportation and sanitation. Secondly, increased violence, lack of incentives for training, disqualification of local labor, unemployment and informal employment were also highlighted.

Studies addressing the potential negative impacts of the activities, processes and products of TTPs on human health showed an increase of air pollutants that cause damage to the health of communities by affecting the respiratory tract (62%), skin (13%) and vision (25%).

The reconfiguration of land use and land cover produced changes in the organization of the communities, notably the predominance of semi-urbanized areas that reduced the flow of bodies of water that drain the region due to silting by erosion, which was attributed to the devastation of their riparian forests due to the installation of the project in that area.

Therefore, this study indicated that the challenges in the area were not limited solely to geographic and environmental issues. Rather, they incorporate regional aspects that comprise planning, transportation, water, sanitation, health, education, safety, infrastructure, environment and waste, which, due to the lack of government intervention, ultimately impede the quantification of the installed project's impacts in the industrial area of São Luís island.

Acknowledgements

The authors thank the Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão (FAPEMA), by the financial support for the accomplishment of this work.

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